Optimizing tuned auxiliary structures for power harvesting

1. Abstract

In many applications, such as structural health monitoring and damage prognosis, it is desirable to have autonomous, self-contained sensor systems. Systems that depend on batteries have maintenance requirements (replacing batteries) and can fail at inconvenient times. If power can be supplied by ambient sources then the system has a potentially unlimited life span. As power requirements for electrical devices decrease, the possibility exists that localized power generation using ambient sources will be adequate to meet these power requirements. The process of acquiring ambient energy is called power or energy harvesting. Forms of energy that may potentially be harvested include thermal, vibration, acoustic, and solar. The purpose of this study is to determine if power harvesting from mechanical vibration using piezoelectric (PZT) materials can be enhanced using tuned auxiliary structures. These structures are to be designed to maximize the strain induced in the PZT material.

2. Project Outline – (about 1 page long)

2.1 Goal - What the project should accomplish.

- Investigate the concept of power harvesting.
- Investigate how to optimize tuned auxiliary structures for enhancing power harvesting.

2.2 Motivation – Why the project is important and how it fits into the "big picture" of real world structural dynamics.

- There is a need for self-powered autonomous sensing systems.
- Ambient vibration and its associated energy is "free."
- Ambient vibration may result in very small amplitude vibration necessitating some way to enhance the power harvesting potential.

2.3. Procedure – Steps needed to complete project.

- Attach PZT material to frame structure.
- Design and build battery charging circuit or resistive circuit to determine power output of PZT
- Create FEM of frame structure
- Measure natural frequencies of frame
- Design various auxiliary structure (different geometries, same natural frequency) tuned to resonant frequencies of the host structure.
- Determine effect of auxiliary structures on the power harvesting
- Use finite element model to match the experimental data and to further design alternative auxiliary structures

3. Background Literature – Pertinent references students should become familiar with before and during the project.

Sodano, H. A., Inman, D. J., Park, G. 2004. "A Review of Power Harvesting from Vibration Using Piezoelectric Materials," The Shock and Vibration Digest, Vol. 36, No. 3, pp. 197-205

Damianakis, M., J. Goethals, J. Kowtko, P. Cornwell, "Enhancing Power Harvesting Using a Tuned Auxliliary Structure," *Proceedings of the 22nd IMAC conference on Structural Dynamics*, Dearborn, MI, Jan. 26-29, 2004. (available at www.lanl.gov/projects/dss)

Do a web search on "power harvesting" prior to arriving in Los Alamos.

4. Week by Week Plan (tentative)

Week 1: (a) Literature review on power harvesting including a patent search
(b) Become familiar with test structure, data acquisition system, shaker, PZT patches, circuit for determining power output, theoretical equation for power out

Week 2: (a) Attach PZT material to frame structure (if the one from last summer is no longer operational).
(b) Design / build circuit for measuring harvested power.
(c) Begin finite element model of frame structure.
(d) Experimentally determine first natural frequency of the frame structure.
(e) Design auxiliary structures

Week 3: (a) Begin power harvesting experiment on frame structure.
(b) Manufacture auxiliary structures tuned to several natural frequencies (use different geometries).
(c) Use finite element model to examine alternative designs (very flexible for example).

Week 4/5/6: Carry out tests on the of the power harvesting. Determine effect of various amplitude inputs, different geometries. Try modified design. Correlate results with finite element model.

Week 7/8: Report / Technical Paper writing / drafting presentation material, actual presentation.

5. Real World Design Issues as a Project Consideration.

- There are already some patents related to power harvesting. Are any of these relevant to this project?
- What are some of the practical design issues associated with power harvesting?

6. Equipment Requirements.

- PZT patches
- Breadboard and electronic components.
- Shaker / Amp + force transducer + one lightweight accelerometer
- Data acquisition

- Spectrum Analyzer or equivalent.
- Impulse hammer (if first frequency found using a tap test).
- If a model analysis of the frame structure is performed more accelerometers will be required.

7. Software Requirements.

- ABAQUS.
- MEScope (possibly)